

# Cosmic Ray Tagger for the *GRAIN* full-scale prototype @ LNL

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***DUNE-Italy Collaboration Meeting***

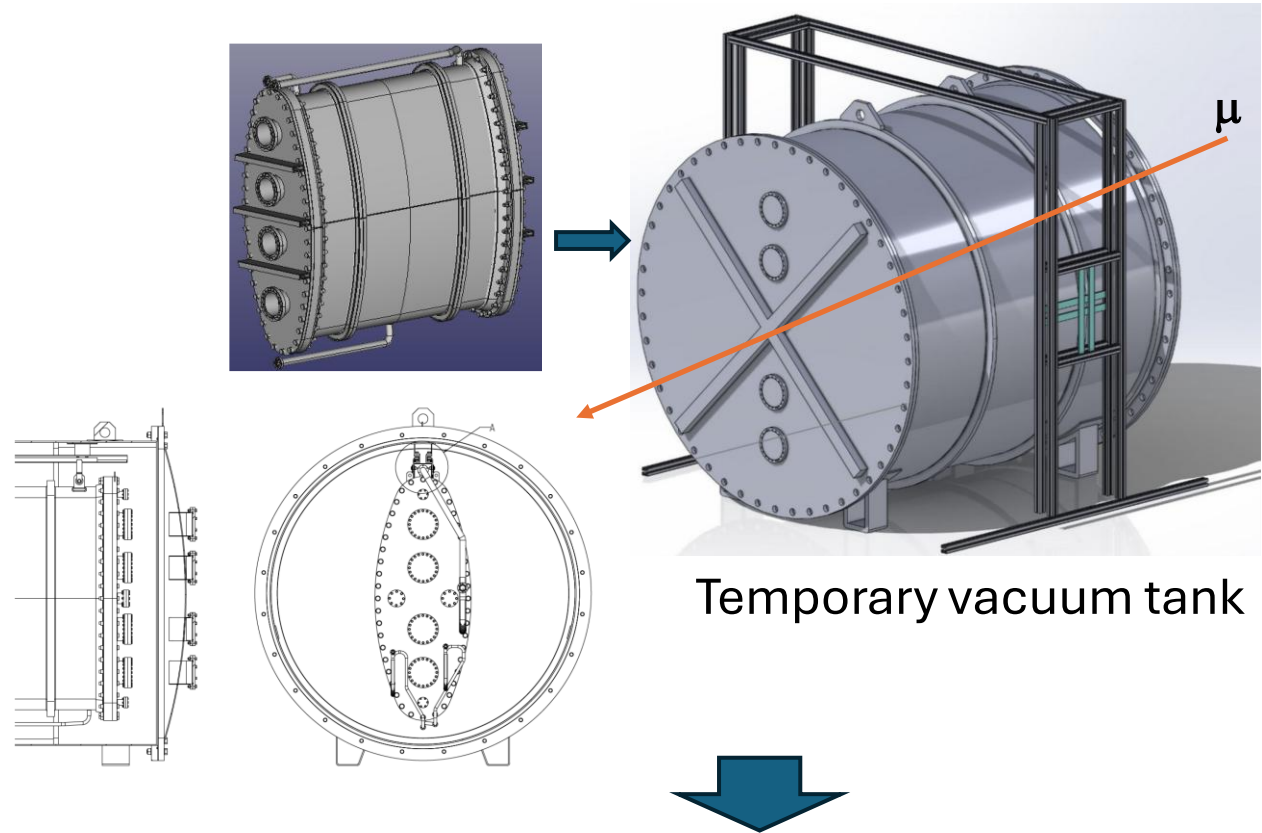
**LNF, 10-12 November 2025**

# GRAIN full-scale prototype @ LNL

**A full-scale prototype of GRAIN will be installed and operated at Legnaro INFN Laboratory**

**In order to test the:**

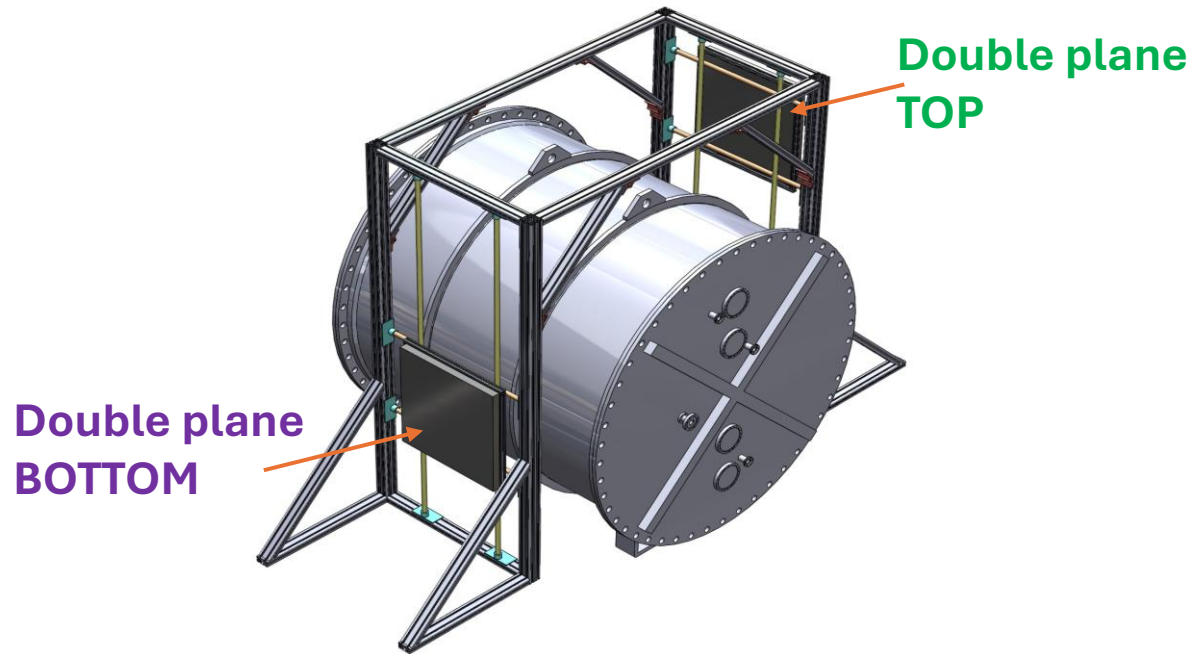
- **mechanics**
- **integration in vacuum tank and cabling**
- **operation conditions**
- **detector response**
- **performance of**
  - read-out system
  - event reconstruction



**A Cosmic Ray Tagger will provide**

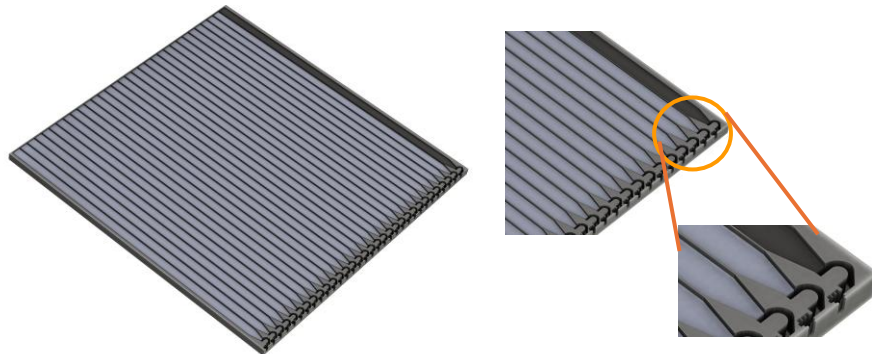
- trigger for imaging system readout
- tracking of throughgoing muons

# Cosmic Ray Tagger (CRT) layout



- Trigger on cosmic muons from fourfold coincidence of **two couples of plastic scintillator planes**, one on each side
- Each plane made of **32 bars of dimensions: 70 cm x 2 cm x 1 cm**
- Bars arranged orthogonally in the 2 planes of each couple, for a **good tracking resolution**

➤ Tray with 32 slots + readout f.e. housing



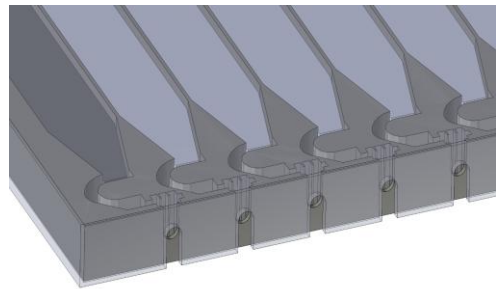
SCINTILLATORS:  
Saint Gobain BC-408

- Design in progress for:
  - mechanical structure
  - tray couple movement system (both on vertical and horizontal axis)

# CRT: read-out and trigger logic design

- One read-out channel for each bar

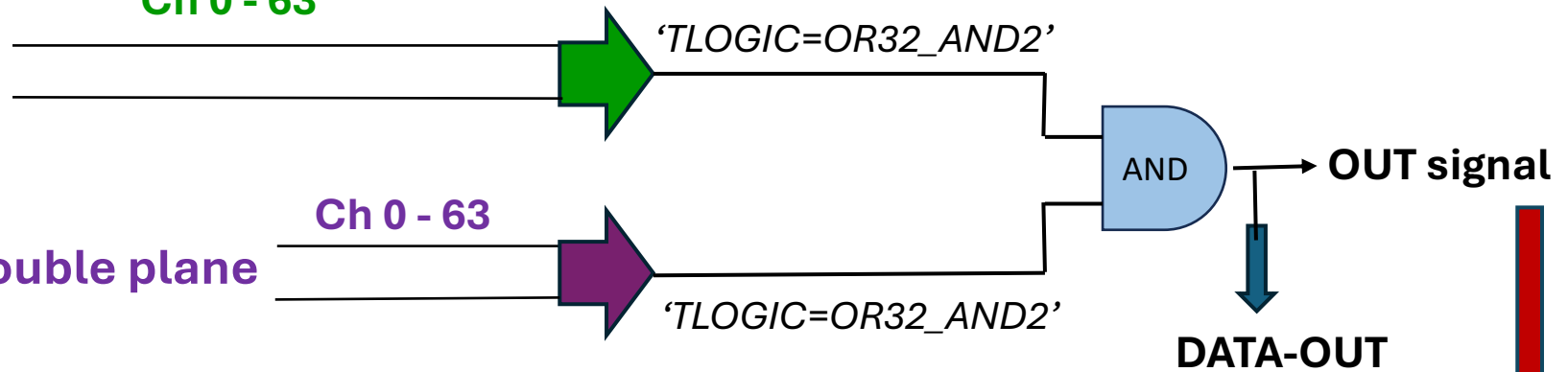
1<sup>^</sup> side double plane



Ch 0 - 63

2<sup>^</sup> side double plane

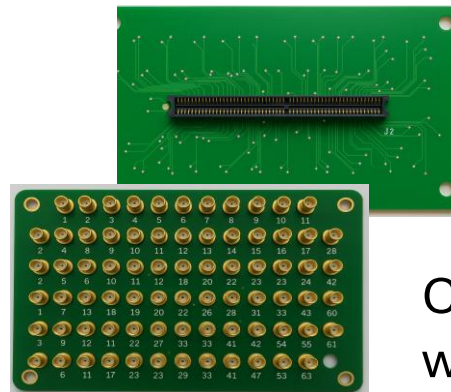
Ch 0 - 63



**64 ch's DAQ BOARD**

CAEN FERS - DT5202

2 x



Custom back-plane  
with MCX connectors

Trigger to  
the GRAIN  
read-out  
system

# CRT: design status and prototyping

## BAR READ OUT:

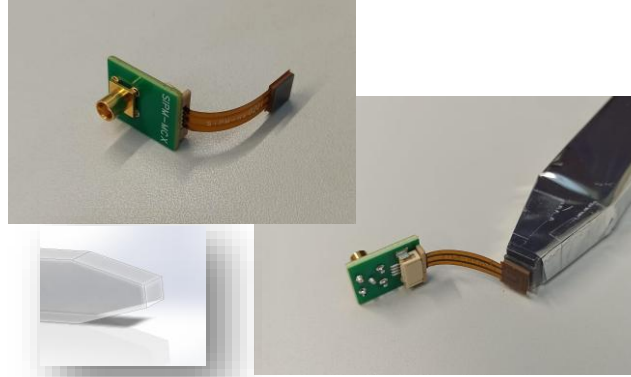
6x6 mm<sup>2</sup> SiPMs

Hamamatsu S14160-6050HS

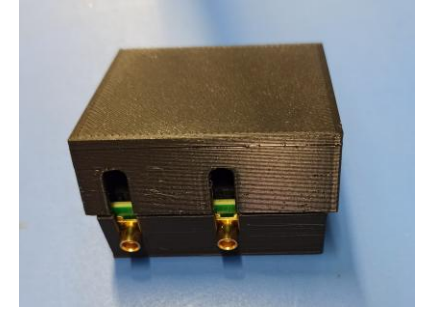
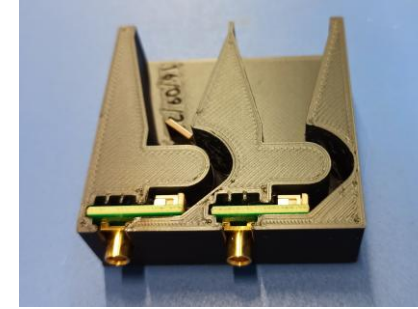
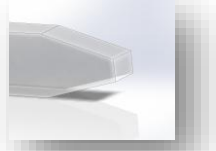
14331 pixels and 50  $\mu$ m pitch



## Custom Front-End readout circuit (kapton flex cable)



Optical interface sheet to match the SiPM to the bar edge



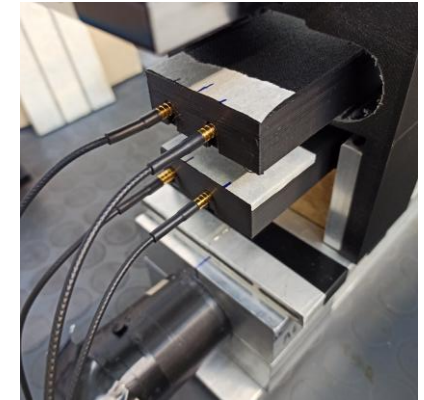
Tray and cover made by means of 3D printer



Bar wrapping with teflon (PTFE) or mylar (PET) film

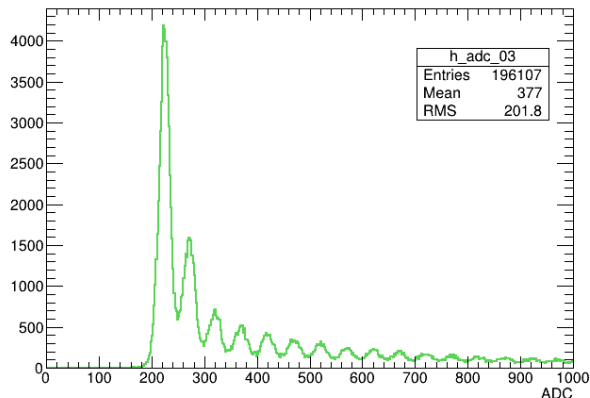
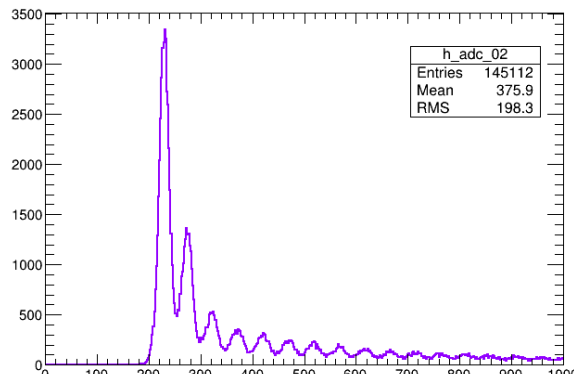


Readout test on Self-Trigger and Ext-muon trigger



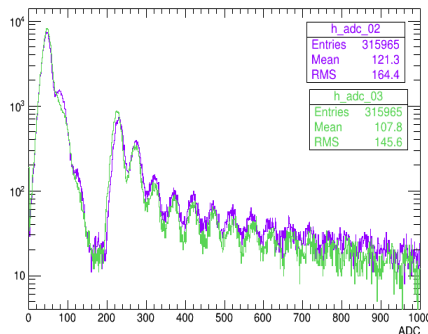
# CRT: test of readout front-end

## ➤ Bar readout in Self-Trigger mode

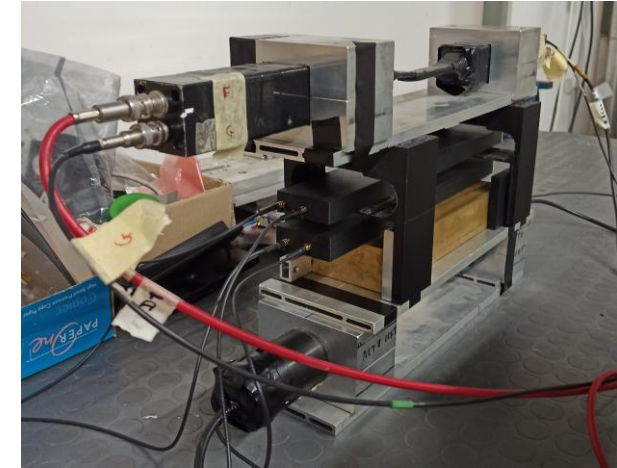


Single p.e.  
spectra

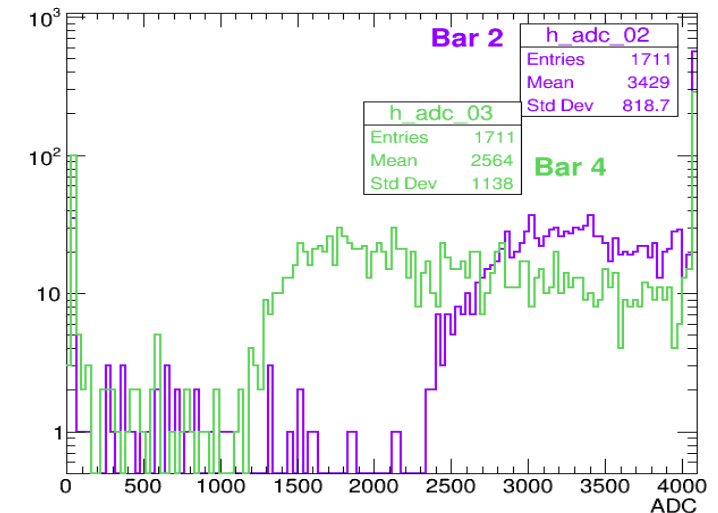
OR of the 2 channels



## ➤ Bar readout on **External** **Muon-Triggers**

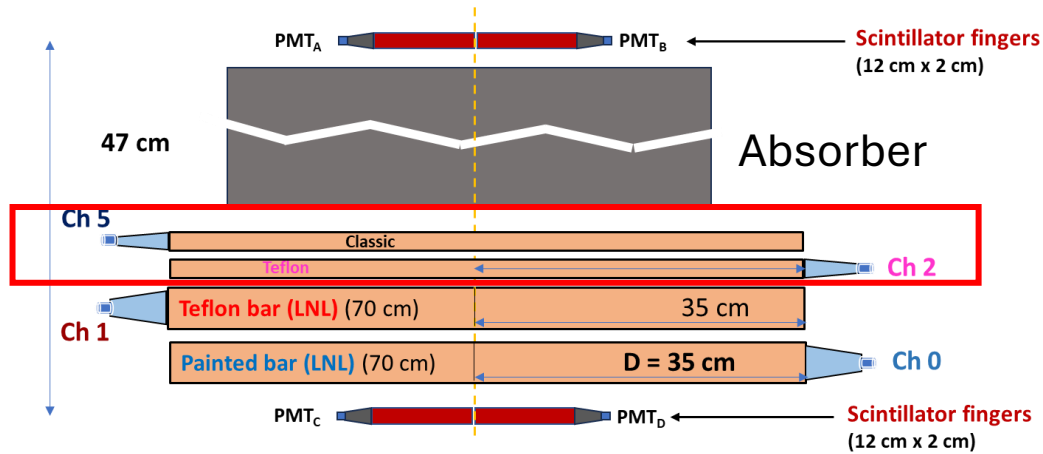


Ch\_2 -> Bar\_2

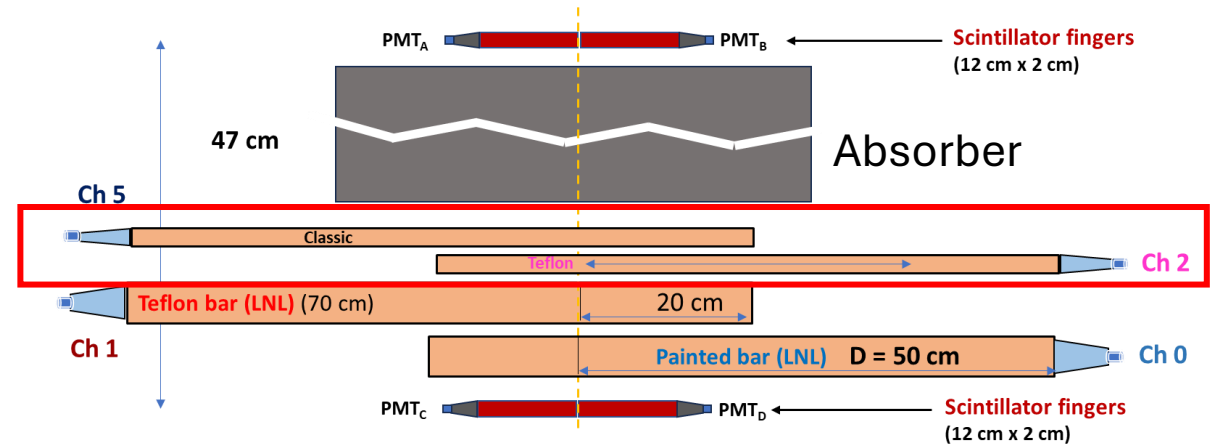
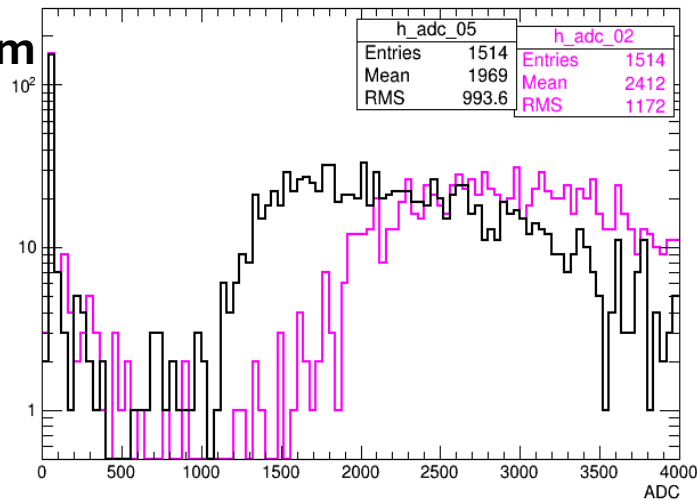


Very robust  
signals  
from muons

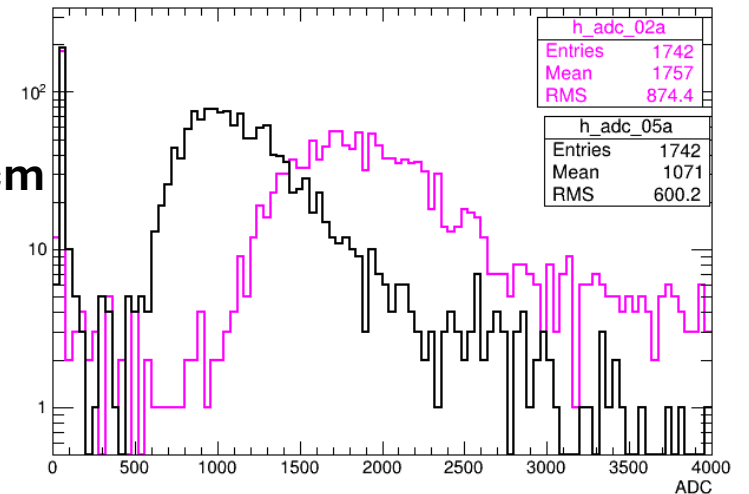
# CRT: test on signal attenuation for 70cm bars



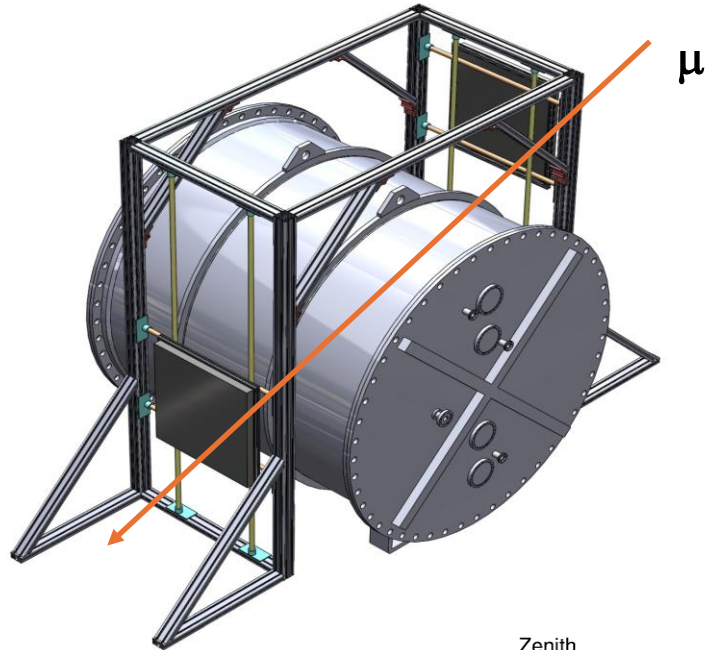
$D(\mu\text{-SiPM}) \sim 35\text{cm}$



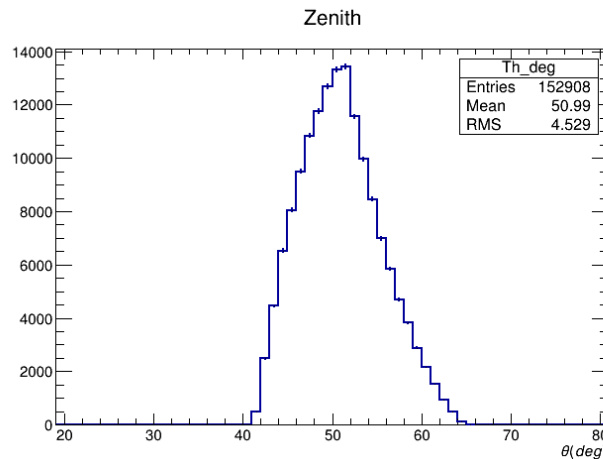
$D(\mu\text{-SiPM}) \sim 50\text{cm}$



# Expected muon rate from CRT @ LNL



Zenith angle distribution



## Monte Carlo simulation with

- TOP & BOTTOM size: 70cm x 70cm
- (T-B) Horizontal Distance: 210 cm
- (T-B) Vertical-Distance: 170 cm

$$\text{Flux} = I_0 \cos^2\theta \quad \text{with} \quad I_0 \approx 72 \text{ /m}^2 \text{ /s /sr}$$

Muon rate on a vertical surface A (one side):  
Rate  $\approx 44 \mu \text{ /m}^2\text{/s} * A \rightarrow \text{Rate(TOP)} \sim 20 \mu \text{ /s}$

➤ From the simulation:

- Geometry "acceptance" of (T+B):  $\approx 0.015$
  - **Expected Muon Rate:  $\sim 0.3 \text{ Hz}$  ( $\sim 1100 \mu \text{ /h}$ )**
- $\rightarrow \sim 10^3 \text{ tracks /h}$  (inefficiency, track reco, ..)

# Conclusions

## ✓ Completed

- Design of basic sensitive Cosmic Ray Tagger element:  
tray with 32 slots for housing of scintillator bars with cover for light shielding
- Realization of some (shorter, double slot) tray prototypes  
(→ thanks to S. Maggiore of Mechanics team of INFN-Lecce)
- Custom design of the single bar readout front-end circuit and of the DAQ board back-plane with CMX connectors  
(→ thanks to A. Corvaglia of the Electronics team of INFN-Lecce)
- Test and validation of the readout front-end on both self- and external-muon triggers
- Muon signal attenuation measurement on 70 cm long bars

## ✓ In progress

- Design of mechanical structure and tray movement system (vertically and horizontally)
- Cutting and shaping of scintillator bars